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PHYTOPATHOLOGY

VOLUME X NUMBER 5

MAY, 1920

# OBSERVATIONS ON SOME COMMON AND IMPORTANT DISEASES OF THE RHODODENDRON[1]

HENRY SCHMITZ

WITH PLATE XI

The purpose of the present paper is to briefly discuss some of the common and more important diseases of the native and cultivated Rhododendrons of the Pacific Coast. It is fully appreciated that some of the diseases here discussed have been described in other connections, and their presence on Rhododendron reported, but their relations to this host seem to have been little investigated. It must be understood that the treatment which follows does not attempt to be exhaustive in detail, but the work was undertaken with the idea of bringing together in one place the important diseases of this shrub on the Pacific Coast.

## ARTIFICIAL INOCULATIONS

The general texture of the Rhododendron leaf is very tough, so that great difficulty was at first experienced in keeping the spores moist long enough to insure germination and the proper establishment of the mycelium. To overcome this difficulty, glass rings were sealed to the leaf with a mixture of one part of paraffin and three parts of beeswax. The spores in water were then placed within and a cover glass sealed onto the ring. This kept the spores under excellent conditions for germination.

With some fungi, such as Sporocybe, spores were formed in artificial culture only after long periods of time, while in other instances, as Cryptostictis, the mycelium failed to produce spores under the various conditions of temperature maintained, even after a year's growth. This

[1] The writer wishes to express his indebtedness to Dr. J. W. Hotson of the University of Washington, under whom the work was done, for his kind suggestions and helpful criticisms; to Prof. Roland Thaxter for assistance in the determination of some of the fungi; and to the Missouri Botanical Garden for the privileges of the herbarium.

made it necessary in some of the artificial inoculation experiments to take the spores directly from the bud or leaf as the case might be. This method is not in strict accord with common practice in artificial inoculation experiments, but there is sufficient evidence that the causal agent was the particular fungus in question.

In all cases cultures were again made from the artificially inoculated area and the fungus therein reobtained and compared with the original fungus.

### SPOROCYBE AZALEAE (PK.) SACC.

*Sporocybe azaleae* produces a "bud rot" disease of Rhododendron. Plants affected by the disease are easily recognized at all times of the year, the brown, dead buds being very conspicuous in contrast with the whorl of green leaves which surrounds them. Examination of the diseased bud shows the fruiting bodies of the fungus protruding in all directions.

In the early stages of infection, the bud scales become only slightly browned; later they become dark brown, and still later the fruiting bodies appear. The fungus may also work down the stem, killing the bark and the cambium. Plate XI, figures 6 and 10, illustrate the appearance of this disease on the buds, branches, and pods.

Buds artificially inoculated with spores of *Sporocybe azaleae* in May produced fruiting bodies of the fungus by September. Spores of the fungus were shaken down between the bud scales with little or no injury to the bud. The buds so infected did not open but were killed by the fungus, while buds slightly injured in a similar manner and not inoculated opened normally.

Bud rot is perhaps the most serious disease of the native *Rhododendron californicum*, and is yearly becoming more prevalent on the cultivated varieties. Spraying will probably not serve to control it on the cultivated varieties, owing to the deep-seated nature of the disease in the buds, and it is suggested that the buds be cut out and burned as they become infected.

### MELAMPSOROPSIS PIPERIANA ARTHUR

*Melampsoropsis piperiana*, or "Rhododendron rust," is found in great abundance on the leaves of *Rhododendron californicum*. It has not been found by the writer on the cultivated varieties.

Melampsoropsis produces numerous small, reddish-yellow pustules on the lower surface of the leaves. These may at times be so numerous that they run together, forming a large blotch. Very often the margin is the only portion of the leaf affected, forming a reddish-yellow line com-

pletely around the leaf, about one-half centimeter from the edge. The effects of the rust are quite conspicuous, and the disease is easily distinguished from the other diseases of the Rhododendron by the yellowish spores.

Two large spore crops seem to be produced each season in this region. During the latter part of April (1915) a great number of leaves were found to be affected and spores were very abundant. By September of the same year only an occasional spore-bearing leaf was found. Late in November, however, great numbers of spores were found in the same locality. This periodic formation of spores may, of course, be entirely dependent upon weather conditions.

As has been said, the rust was not found on Rhododendrons under cultivation, but there is no reason why it might not occur on a cultivated plant. If it should occur, spraying with Bordeaux mixture in April would no doubt be helpful.

Plate XI, figure 1, shows the characteristic appearance of leaves affected with *Melampsoropsis piperiana*.

### WITCHES' BROOMS

Conspicuous brooms are common on the native Rhododendron. They may reach considerable size and attain great age.

The exact cause of the broom has not been determined. Cultures made from portions of the branches of the brooms in numerous cases produced a mycelium very much resembling that of *Sporocybe azaleae*. The mycelium did not produce spores and therefore could not be identified.

Whether *Sporocybe azaleae*, *Melampsoropsis piperiana*, or some other fungus or insect causes these brooms is a point to be cleared up by future investigations.

The general appearance of the brooms is shown in plate XI, figure 3.

### WHITE LEAF

By "white leaf" a peculiar leaf condition is referred to in which a leaf or cluster of leaves may be partially or entirely devoid of chlorophyll. This condition is quite common in the case of *Rhododendron californicum*. There is no evidence of any fungus or other injury of any kind on such leaves.

Very often, although not always, this condition is found in connection with "witches' brooms." The trouble may be non-parasitic or it may be due to the action of a fungus lower down on the stem or in the roots. If the latter condition is the cause, it is somewhat analogous to the "white spot" condition occurring on alfalfa.

### LOPHODERMIUM RHODODENDRI CES.

*Lophodermium rhododendri* Ces. is reported as causing a leaf disease of Rhododendron both in Europe and in the United States. It is common on *Rhododendron californicum* on the Pacific Coast.

The fungus produces small, boat-shaped perithecia on the upper surface of the leaves. The deadened portions of the leaves usually have an irregular marking encircling from three to seven of the fruiting bodies. This condition is shown in plate XI, figure 4.

As a rule, the fungus is found on leaves entirely dead and lying on the ground. Whether the fungus originally killed the leaves or whether the defoliation was due to other causes, is not known. In several cases living leaves with only small dead areas were found. *Lophodermium rhododendri* was the only fungus observed on the dead areas. This would suggest that the fungus mentioned may be the parasite involved.

Owing to the imperfect condition of the material, no pure cultures of Lophodermium were obtained.

### COCOMYCES DENTATUS (KEZ. ET SCHM.) SACC.

The exact species of Coccomyces here involved is questionable, but is provisonally referred to *Coccomyces dentatus* (Kez, et Schm.) Sacc. It is very abundant both on the leaves and twigs of the native Rhododendron.

The effects of the fungus on the leaf are similar in appearance to those produced by *Lophodermium rhododendri*, except that in this case the perithecia are more or less star-shaped.

Fruiting bodies were never found except on dead leaves, and it is still a question whether or not Coccomyces is the killing agent. The fungus is, however, found on living stems and seems eventually to kill the twigs.

Very good material of the fungus was not found. Although numerous attempts were made, no pure cultures were obtained and satisfactory inoculation experiments were therefore precluded. The general appearance of leaves and twigs affected by this fungus is shown in plate XI, figures 2 and 9.

### CORYNEUM RHODODENDRI S.

This species of Coryneum was found quite prevalent on the leaves of cultivated varieties of Rhododendron. The fungus causes irregular dead areas on the leaves. Very often a dead strip entirely around the leaf may be found. There is also some evidence that it grows on the portions of the leaves killed by aphids. Leaves slightly injured with a hot needle and inoculated with spores of the fungus produced the typical disease and spores after two and one-half months' growth under greenhouse

conditions. The controls showed no further changes than the small deadened areas due to the hot needle punctures.

Plate XI, figure 8, shows the general appearance of leaves infected with *Coryneum rhododendri.*

### SPHAERELLA RHODODENDRI CKE.

This fungus is found very commonly on the leaves of both the native and cultivated varieties of Rhododendron.

The dead areas have a deep reddish-brown to brown color. The upper surface is slightly roughened, due to the presence of numerous minute perithecia. Very often the dead area includes the tip half of the leaf (plate XI, fig. 5).

No cultures were obtained from the leaves that could be definitely identified as Sphaerella, hence artificial inoculations were made by placing small portions of infected leaves in contact with slightly injured leaves, but in no case did infection result.

In the opinion of the writer, the species of Sphaerella here in question is not parasitic on Rhododendron, but seems to appear on the leaves only after they have been partly or entirely killed by summer or winter desiccation. In its natural habitat, the Rhododendron often suffers from lack of water, and dead areas appear on the leaf which may in every way be identical to those on which Sphaerella is found, except that the fungus is lacking.

### PESTALOZZIA GUEPINI DESM.

The Pestalozzia disease of Rhododendron was found only on plants under cultivation. The deadened areas of the leaves affected by the fungus are usually small and are more or less gray in color. The fungus is often found on leaves after they have suffered from the activities of a small aphid that is quite common in the early spring. The young leaves are affected. Small deadened areas appear, which later enlarge because of infection by Pestalozzia. Plate XI, figure 7, shows the general appearance of the leaves after they have been attacked by the aphid and in the various stages of secondary infection with Pestalozzia.

The usual methods of artificial inoculation were employed and positive evidence was obtained showing that this species of Pestalozzia is parasitic in nature.

### CRYPTOSTICTIS SP.

By this name I refer to a disease found commonly both on the native and cultivated forms of Rhododendron. The area of the leaf killed by this fungus is usually circular or partly so in shape. The concentric rows

of fruiting bodies produced by the fungus are plainly visible, and it is by means of these concentric rings of spore pustules that this disease may be easily distinguished from the other leaf diseases here discussed.

The spores have somewhat the shape and general appearance of spores of Coryneum, and may be mistaken for that form in a hasty observation. They have, however, a characteristic appendage.

In artificial cultures at first a dense, downy mycelium was formed, which later shrank to quite limited dimensions. Spores were not produced on the types of nutrient media used nor under the conditions of growth maintained. For this reason, the spores for the artificial inoculations were taken directly from a diseased leaf. These inoculations showed the fungus to be parasitic in nature, and concentric rings of spore pustules were produced some three months after the inoculations were made. The controls showed no further change than the small deadened areas due to the punctures of the hot needle.

LABORATORY OF FOREST PATHOLOGY,
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## PLATE XI

FIG. 1. *Melampsoropsis piperiana* Arthur. Characteristic appearance of infected leaves.

FIG. 2. *Coccomyces dentatus* (Kez. et Schm.) Sacc. The dark, star-shaped perithecia are common both on the leaves and twigs.

FIG. 3. Witches' broom. A comparatively small dense broom.

FIG. 4. *Lophodermium rhododendri* Ces. Numerous fruiting bodies of the fungus are evident on the upper surface of the leaf.

FIG. 5. *Sphaerella rhododendri* Cke. It is quite probable that Sphaerella rhododendri is saprophytic on the dead areas of the leaves.

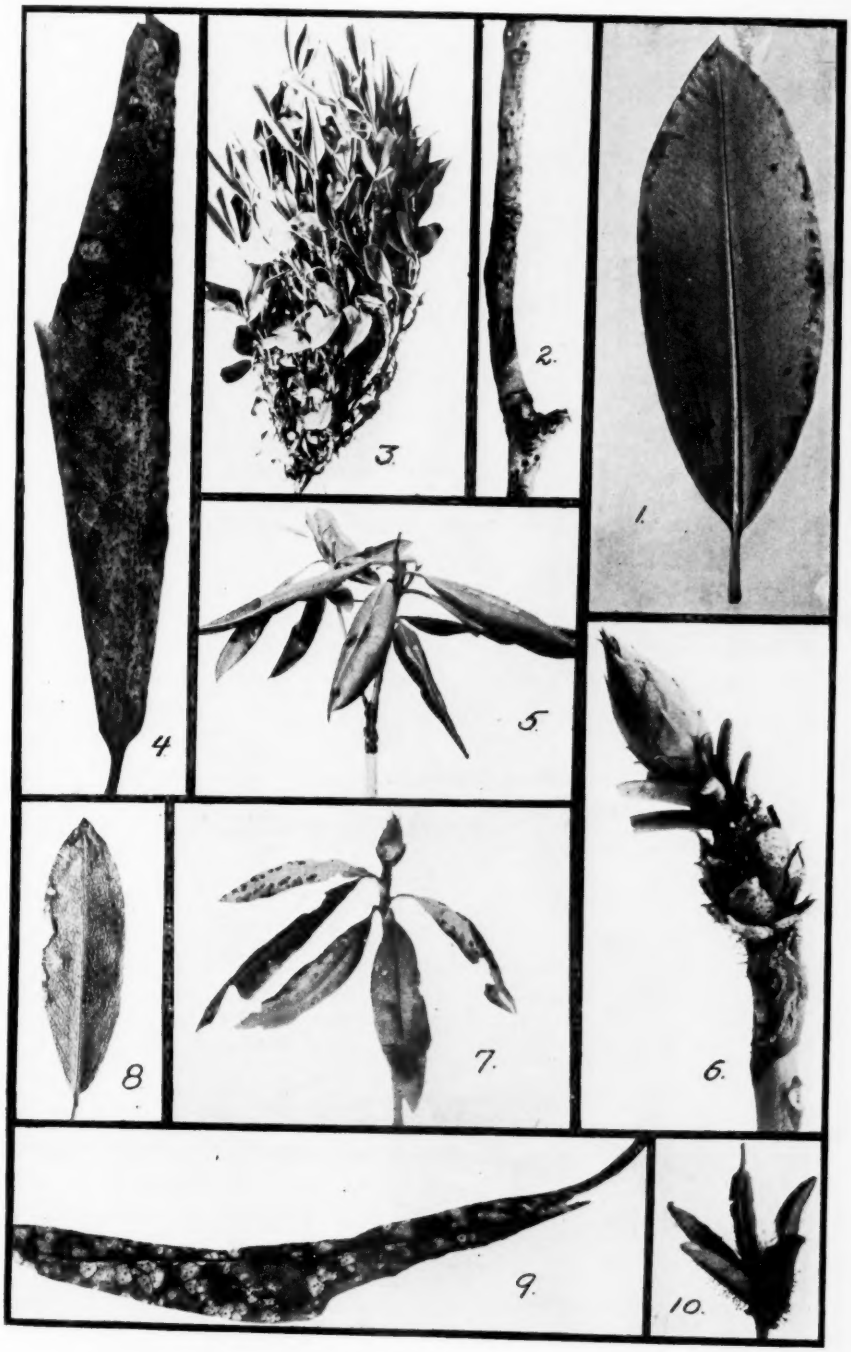
FIG. 6. *Sporocybe azaleae* (Pk.) Sacc. The fungus kills the branches as well as the buds. Branch infection usually results from bud infection as here shown.

FIG. 7. *Pestalozzia guepini*. Desm. A typical Pestalozzia infection. The infected areas may, however, increase in size until the entire leaf is killed.

FIG. 8. *Coryneum rhododendri* S. The infection is usually more or less confined to the periphery of the leaf.

FIG. 9. *Coccomyces dentatus* (Kez. et Schm.) Sacc. The fruiting bodies appear as small spots on the light-colored areas of the leaf.

FIG. 10. *Sporocybe azaleae* (Pk.) Sacc. An infected seed pod.




SCHMITZ: RHODODENDRON DISEASES

# FACULTATIVE HETEROECISM IN PERIDERMIUM CEREBRUM AND PERIDERMIUM HARKNESSII

E. P. MEINECKE

WITH TWO FIGURES IN THE TEXT

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In the year 1916 report[1] was made of successful infections of *Pinus radiata* as a result of direct inoculation with aeciospores of *Peridermium harknessii* Moore from *Pinus radiata*. Owing to totally inadequate laboratory and greenhouse conditions, the experiments at that time had been confined to two plants with two control plants. One inoculated plant died; on the other, seven inoculations were made, of which five produced typical galls and aecia.

It was concluded that, if *Peridermium harknessii* Moore was indentical with *Peridermium cerebrum* Peck [*Cronatrium cerebrum* (Peck) Hedgc. and Long], field observations as well as inoculation results made it appear that in California, at least within the range of the old *Peridermium harknessii*, the aecial form on one side and the uredinial and telial on the other must be highly independent of each other, and that the heteroecism of the fungus is facultative.

The revolutionary character of the result of the inoculations made it imperative that the experiments be repeated on a larger scale, in order to put the facts themselves beyond the reach of criticism, before an interpretation of the phenomenon in the light of prevailing theories could be attempted.

[1] Meinecke, E. P. Peridermium harknessii and Cronartium quercuum. Phytopathology, **6**: 225–240, 2 fig. Je. 1916.

At the time of publication all endeavors to connect the so-called *Peridermium harknessii* with *Peridermium cerebrum* had failed. Since then, Hedgcock[2] has succeeded in producing uredinia and telia on *Quercus velutina* with aeciospores from *Pinus radiata*, thereby indicating the identity of the coast form with *Peridermium cerebrum* Peck. Still it must be noted that to the present day no pycnia have been found on the thousands of the coast galls examined, and that the many inoculation experiments with aeciospores on *Quercus agrifolia* and *Q. californica*, as well as with teliospores on *Pinus radiata*, have failed to produce results. *Quercus agrifolia* is very commonly associated with *Pinus radiata* and often harbors the uredinia and telia of what is called *Cronartium quercuum*. While the failure to infect the alternate host may possibly be due to a series of unfavorable circumstances, the absence of pycnia is distinctly surprising. Neither do they appear in nature, nor can they be coaxed into development *in vitro*.

The old *Peridermium harknessii* Moore included not only the coast form, now identified with *Peridermium cerebrum*, on *Pinus radiata* and other pines, but also a gall-producing Peridermium on mountain pines, *Pinus sabiniana*, *P. ponderosa*, *P. jeffreyi*, and *P. contorta*. *Pinus radiata* occurs in abundance on the coast at Monterey. *Pinus sabiniana* inhabits the lower fringe of dry foothills, while *Pinus ponderosa* sets in from about 1500 feet and extends to about 6000 feet elevation. *Pinus jeffreyi* becomes abundant from about 5000 feet on, reaches its optimum at 6000 to 6500 feet, and ranges to over 9000 feet. *Pinus contorta* in the central Sierra Nevada grows at an altitude of 6000 to 10,000 feet.

The first mention of *Peridermium harknessii* Moore is made by H. W. Harkness in 1880[3] as follows: "*Peridermium harknessii* n. sp. Moore. On *Pinus ponderosa*, Colfax." Together with this we find: "*Peridermium pini* Fr. On *Pinus insignis*. San Francisco." In 1880 *Peridermium pini*, a European form on *Pinus silvestris*, was still considered to embrace a stem-inhabiting form (*Peridermium pini corticola*) and a needle-inhabiting form (*Peridermium pini acicola*). It may be assumed that Harkness, finding a Peridermium on the stems and *Peridermium californicum* on the needles, associated on *Pinus radiata* (*P. insignis*), followed the error of contemporaneous European authors and considered both as *Peridermium pini*.

[2] Rhoads, A. S., Hedgcock, G. G., Bethel, Ellsworth, and Hartley, Carl. Host relationships of the North American rusts, other than Gymnosporangiums, which attack conifers. Phytopathology, **8**: 309–352. Jy. 1918. Literature cited, p. 346–352.

[3] Harkness, H. W., and Moore, Justin P. Catalogue of the Pacific Coast fungi. Read before the California Academy of Sciences, Feb. 2, 1880. p. 27. [San Francisco, 1880.]

Four years later Harkness[4] dropped *Peridermium pini* and retained only *Peridermium harknessii*. He writes (p. 37): "*Peridermium harknessii* Moore. Spermogones unknown. Protospores: Peridia aggregate, irregular, encircling the stem; spores irregular, very finely echinulate, orange, becoming white. $\mu$. 35–40. On stems and branches of *Pinus insignis*, *P. ponderosa* and *P. sabiniana*. Appearing as annular swellings, often two feet in circumference upon the trunks and branches. In the Sierra Nevada, below the height of 4000 feet and in the Coast Range. Particularly abundant at Monterey. The different species of Peridermium of the pine seem to be doubtfully distinct. H. W. H."

Harkness' type specimens in the California Academy of Sciences were partly rescued from destruction in the conflagration of San Francisco in 1906. We find under no. 2698 (subnumber 449) the bottom of a small pill box with the subnumber 449 (1). The box evidently contained the specimen of which no traces are left. A note in what appears to be Harkness' handwriting reads: "Peridermium found on pine trees near the town of Colfax April 26, '76,—on *Pinus ponderosa* on hillside in rear of the Station. *Peridermium harknessii*." Colfax lies in the foothills on the California side of the Sierra Nevada at an elevation of 2400 feet. The missing specimen must then be considered as the type specimen, collected on *Pinus ponderosa* at Colfax, Cal.

While the type specimen itself has disappeared, there exists a duplicate in the Ellis Collection of the New York Botanical Garden. This specimen is very well preserved and consists of a piece of a branch lengthwise cut in two and glued onto a label with the following legend in Dr. Ellis' handwriting: "*Peridermium harknessii* Moore on *Pinus ponderosa*, Colfax, Calif. Dr. H. W. Harkness (28)." The specimen shows two distinct galls, a larger and a smaller one, which cannot be distinguished from the common form on the pines of the Sierrra Nevada. There cannot be any doubt that Dr. Ellis received this specimen from Harkness and that Harkness himself considered it typical for *Peridermium harknessii* Moore and that the specimen was collected at the type locality.

It is clear that Harkness was not familiar with the gall form on *Pinus contorta* or *Pinus jeffreyi*, both of which occur above 4000 feet elevation, and that his *Peridermium harknessii* (Moore never published on the species) originally referred to the gall form on pines on the lower slopes of the Sierra Nevada. It was only later that he extended this designation to the gall form on *Pinus radiata*.

The galls on the coast pines and those on the Sierra pines are, at first glance, so much alike that they have long been regarded as identical, all

[4] Harkness, H. W. New species of Californian fungi. Bul. California Acad. Sci., No. 1: 29–47. 1884.

the more so since the only Cronartium associated with the High Sierra form had already been connected with *Peridermium filamentosum*. We know now[5] that this Cronartium in reality represents two different forms, one going to the gall form, the other to *Peridermium filamentosum* (syn. *P. stalactiforme* Arth. and Kern), both on *Pinus contorta, P. ponderosa,* and *P. jeffreyi*. The latter Peridermium is the aecial stage of *Cronartium filamentosum* (Peck) Hedgc. and Long. There appears no reason why the former should not be called *Cronartium harknessii* nov. comb.

There is still a great deal of confusion with regard to these last two forms, owing to the fact that both produce apparently identical uredinia and telia on scrophulariaceous hosts. Weir and Hubert[6] in the same paper report experiments with "*Cronartium coleosporioides* (D. and H.) Arth. (*P. stalactiforme* type)," with "*Cronartium coleosporioides* (typical gall form)," and with "*Cronartium coleosporioides* (typical blister type)." Presumably the "typical gall form" refers to Cronartium sp.? of Rhoads, Hedgcock, Bethel, and Hartley,[7] that is, *Cronartium harknessii*. The "*Peridermium stalactiforme* type" is undoubtedly *Peridermium filamentosum* (Peck) Hedgc. and Long. It is less easy to place the "typical blister type," unless here also the *P. stalactiforme* type (*P. filamentosum*) is meant.

At the present time *Peridermium filamentosum* and *P. stalactiforme* are considered identical. Certain striking morphological differences may have a deeper meaning. On *Pinus contorta* the infection of the stem often takes place through small twigs and spreads very evenly up and down the trunk much faster than sideways. The result is a very neat elongated diamond. This form of development does not seem to occur on *Pinus ponderosa* or *P. jeffreyi*, at least not in the Pacific Coast mountains. The aecia on *Pinus ponderosa* often appear in the shape of very conspicuous long cylinders with an unusually tough peridium. This form seems to be unknown on *Pinus contorta*. It is not impossible that the present term *Peridermium filamentosum* covers two different species, both of which go to Castilleia and related forms and there produce uredinia and telia which are indistinguishable from each other and from those of *P. harknessii*. In that case the Castilleia group would harbor

[5] Rhoads, A. S., Hedgcock, G. G., Bethel, Ellsworth, and Hartley, Carl. Op. cit., p. 317.

Weir, J. R., and Hubert, E. E. A serious disease in forest nurseries caused by Peridermium filamentosum. Jour. Agr. Research, **5**: 781–785. Ja. 24, 1916.

These results have recently been confirmed by the author of this paper.

[6] Weir, J. R., and Hubert, E. E. Recent cultures of forest tree rusts. Phytopathology, **7**: 106–109. Ap. 1917.

[7] Op. cit., p. 317.

three uredinia and telia which can only be separated by cultural studies. Experiments are on the way to clear up this point.

We have, then, two gall-forming Peridermia on pines on the Pacific Coast, one erroneously called *Peridermium harknessii* Moore, now *Peridermium cerebrum* Peck (fig. 1), on *Pinus radiata*, *P. attenuata*, and *P. muricata*, and another on *Pinus sabiniana*, *P. ponderosa*, *P. jeffreyi*, *P. contorta*, and perhaps *P. attenuata*, representing the true *Peridermium*

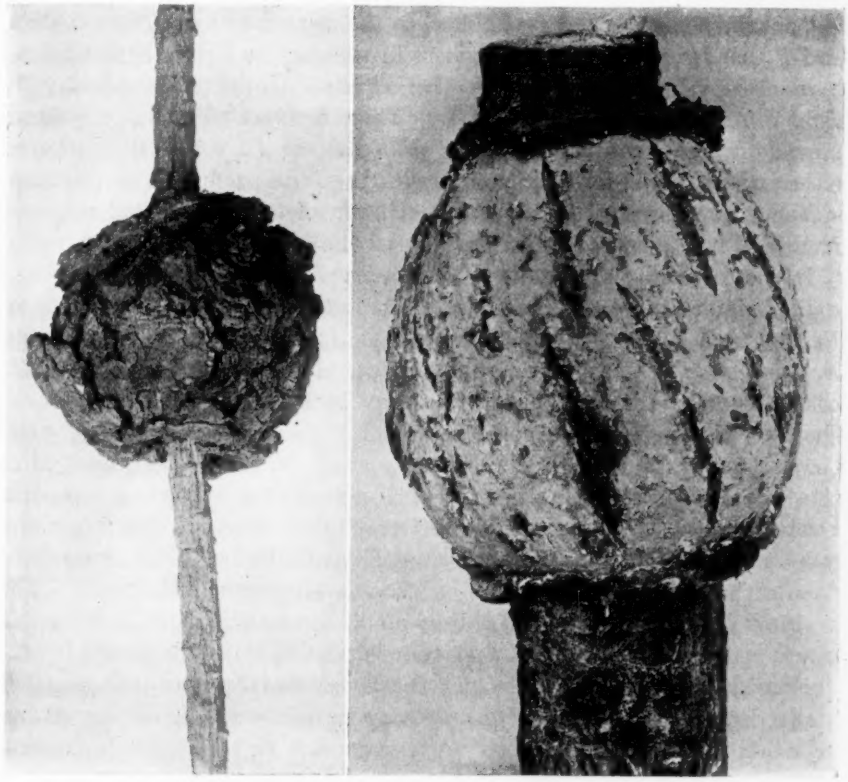

FIG. 1 FIG. 2

FIG. 1. MATURE GALL OF PERIDERMIUM CEREBRUM PECK ON PINUS RADIATA

The aecia break forth in the cracks between the bark scales. (Natural size.)

FIG. 2. MATURE GALL OF PERIDERMIUM HARKNESSII MOORE ON PINUS PONDEROSA

Note the collar and the large, naked, spore-covered surfaces resulting from the peeling off of large pathological bark scales. (Natural size.)

*harknessii* Moore (fig. 2). The latter form is still thought by Weir and Hubert[8] to be identical with *Peridermium filamentosum* (Peck) Hedgc. and Long. The same authors[9] consider the various caulicolous forms of rusts occurring on *Pinus contorta* and *P. ponderosa* in the Rocky Mountain region as the aecial stages of *Cronartium coleosporioides*, and believe it "not only possible but probable that the same forms on *Pinus contorta* and *P. ponderosa* as known elsewhere in the western United States belong here also." Rhoads, Hedgcock, Bethel, and Hunt[10] are undoubtedly right in refusing to accept this view. There are vast regions in the Sierra Nevada where *Pinus contorta*, *P. ponderosa*, or *P. jeffreyi* are affected either with the gall-forming rust or with the form producing no or inconspicuous swellings, to the absolute exclusion of the other. If both were identical, surely one would expect to find the forms intermingled.

In the early stages the galls of *Peridermium cerebrum* as found on *Pinus radiata* and other coast pines are difficult to distinguish from those of *Peridermium harknessii* on *Pinus contorta*, *P. jeffreyi*, *P. ponderosa*, and *P. sabiniana*. Later, even before the appearance of the aecia, the galls of *P. harknessii* become rough, and the bark breaks open, the cracks showing plates of young, corky tissue of a chestnut-brown color, while the galls of *P. cerebrum* generally remain smooth for a while, even after the formation of aecia has begun. The aecia of the latter are comparatively small, and appear singly and irregularly scattered, later becoming more or less confluent. Relatively small pathological bark scales keep pace with the growth of the gall and the development of the aecia. The aecia of *P. harknessii*, on the other hand, are much larger and become confluent to such an extent that they often form very large spore-producing surfaces. The pathological bark scales are large and come off easily, leaving wide, smooth spore-covered areas exposed. These pathological bark scales finally reach to the cambium and make further formation of aecia on those areas impossible. The scales break away and the smooth, naked, hypertrophied wood of the gall appears. Another characteristic of the *P. harknessii* gall is the formation of a collar of dead bark standing out from the upper and lower end of the gall. This collar as a rule is absent in *P. cerebrum*, as are also in general the large bark scales and the wide areas of exposed surfaces. The peridium of *P. cerebrum* is rather delicate and ruptures irregularly, while the circumscissile peridium of *P. harknessii* often persists in the form of broader flakes. In general, the galls of *Peridermium cerebrum* are sphaeroid to pear-shaped

[8] Op. cit., 1916, p. 783.
[9] Op. cit., 1917, p. 107.
[10] Op. cit., p. 317.

in their youth and later become more and more spherical, while those of *Peridermium harknessii* show less of a tendency to become truly spherical but remain more pear-shaped, well set off below against the branch of the host and tapering to the upper end. There are, however, many exceptions to this rule.

About 30 to 50 per cent of the galls both of *Peridermium cerebrum* and of *P. harknessii* are accompanied by witches'-brooms.

On the basis of the descriptions given above it is possible to distinguish mature galls of *Peridermium cerebrum* on the coast pines and of *P. harknessii* on the mountain pines.

Harkness' specimen in the Ellis Collection of the New York Botanical Garden answers in every detail the description given here for *Peridermium harknessii*. The collar is very pronounced in both galls, sharply setting off above and below the large and smooth spore-producing surfaces. In the rich collections of the San Francisco laboratory of Forest Pathology, both forms could be segregated without much difficulty. All galls of *Pinus contorta*, *P. jeffreyi*, *P. ponderosa*, and *P. sabiniana* were typically of the *Peridermium harknessii* type. All mature galls on *Pinus radiata* showed the characters of *P. cerebrum*. Of five specimens of galls on *Pinus attenuata*, however, three plainly belonged to the *P. cerebrum* type while two approached the *P. harknessii* type. *Pinus attenuata* has a range extending from the ocean shore to over 5000 feet in the Sierra Nevada, that is, from the range of *Peridermium cerebrum* well into the range of *Peridermium harknessii*. It may well be that this pine is susceptible to both forms. The presence of uredinia (*Uredo coleosporioides* Diet. and Holw., so called) on *Castilleja foliolosa* and others near the coast may be explained as coming from infections from *Peridermium harknessii* on *Pinus attenuata*, though the mild climate of the California Coast makes overwintering in the uredinial form on Castilleja quite probable. The telial form has not yet been found.

Inoculations of *Castilleja foliolosa* from San Francisco with aeciospores of *Peridermium cerebrum* from *Pinus radiata* failed.

Since the publication of the first paper in 1916, *Peridermium cerebrum* has been found on *Pinus muricata* at Santa Barbara, Cal., and on a cultivated specimen of *P. halepensis* at San Mateo, Cal. Uredinia as well as telia were collected in August and September on *Quercus californica*; uredinia at Gilroy, Santa Clara Co., Cal., telia at the same place, both by J. W. Sheldon, and uredinia near Sonora, Cal., by the author. At Gilroy the nearest pines were at least five miles away.

EXPERIMENTS WITH PERIDERMIUM CEREBRUM

Unfortunately a series of experiments on *Pinus radiata* with pedigreed material (results of the former inoculations) was lost when the inoculated plants died owing to poor greenhouse facilities. The new series have not yet shown results.

The experiments here reported and inaugurated for the purpose of confirming the first success were made with wild material.

The same method of inoculation was employed throughout. The aeciospore material was dusted or shaken onto a small quantity of tap water in a watch crystal. It should not be taken with an instrument directly from the aecium, in order to avoid a possible admixture of viable mycelium. With a small sharp scalpel tangential slits about 0.5 to 0.75 cm. in length and not more than 0.5 cm. in width were cut in the living bark of the test plants. The scalpel, after effecting a longitudinal incision through the cortex, passes the cambium without cutting the wood and makes its exit through the epidermis opposite to the line of entrance so that the slits extend through all cortical tissues. The resulting membrane of cortical tissues remains attached above and below, but can easily be bulged out to allow insertion of the inoculum. The latter is introduced with the same scalpel and the membrane is pressed into position. The lips of the wound readily stick together and the membrane fully protects the inoculum from drying out. No further precautions are necessary beyond the usual sterilization of tools, etc., and the protection of the plants from spurious infection, either with bell jars or with celluloid tubes as described by Hubert, until the wounds are healed.

In the earlier experiments the wounded part of the stem was wrapped with cotton which was kept moist for a number of days and then removed. It appears unnecessary to follow this procedure.

All the material used came from typical, more or less spherical, hemispherical to pyriform galls, in which the aecia form separately, are sometimes confluent, but hardly can be called typically cerebroid.

*Inoculations on Pinus radiata with aeciospores from Pinus radiata.* Including the first reported experiment, thirty-eight inoculations on fifteen plants were made under controlled conditions. Of these, nineteen have been successful. Some of the galls resulting are richly sporulating, others are still too young to fruit. All are typical in shape and all developed from the inoculated wound. All control plants are perfectly sound.

*Inoculations on Pinus muricata with aeciospores from Pinus radiata.* Eleven plants were inoculated in twenty-two places. Of these inoculations, twelve were successful, typical galls being formed. One of these has two aecia at the present day.

*Inoculations on Pinus radiata with aeciospores from Pinus attenuata.* One plant was inoculated in four places. One of these four inoculations was successful. The gall produced is sporulating richly.

The galls invariably developed at the point of inoculation and at this point only. All check plants remained sound.

In the foregoing experiments more plants were inoculated than are here given. From different causes a number of the young inoculated trees died. Some of these had developed small galls. They are, however, not counted as positive results.

Accepting only definite results, the total number of infections of *Pinus radiata* and *P. muricata* with aeciospores from *Pinus radiata* and *P. attenuata* amounts to thirty-two out of a total of sixty-four inoculations, or 50 per cent.

Analyzing the effect of the time of inoculation on the percentage of results, we arrive at the following table:

| HOSTS | DATE OF INOCULATION | WOUNDS INOCULATED | POSITIVE INFECTION | PER CENT |
|---|---|---|---|---|
| P. att.-P. rad. | Mar. 26 | 4 | 1 | 25 |
| P. rad.-P. rad. | Apr. 14 | 4 | 1 | 25 |
| P. rad -P. rad. | Apr. 14 | 3 | | 0 |
| P. rad.-P. mur. | Apr. 18 | 6 | | 0 |
| P. rad.-P. rad. | Apr. 18 | 10 | 3 | 33 |
| P. rad.-P. rad. | May 10 | 14 | 10 | 71 |
| P. rad.-P. mur. | May 10 | 16 | 12 | 75 |
| P. rad.-P. rad. | May 23 | 7 | 5 | 71 |

While inoculations earlier than May are not impossible, the best chances for positive results seem to lie in the month of May, due either to the then attained maturity of the spores or to the condition of the inoculated host. In nature the galls begin to fruit as early as December and are usually in full sporulation in the months of March and April. It is to be noted that for a large part of the inoculations here reported, plants of the same origin were used. The plants of *Pinus radiata* and *P. muricata* inoculated on April 18 and May 10 respectively were all raised together from seed in the nursery. Here the result stands 0 and 33 per cent as against 71 and 75 per cent.

During the most favorable time the average of positive results amounted to 63 per cent.

In no case were pycnia or anything resembling these bodies noticed. This tallies with observations of thousands of galls in nature. The microscope so far has failed to reveal any indication of abortive or internal pycnia. Pycnia are common in *Peridermium cerebrum* of the East. In

Japan they are produced in such frequency[11] that "children lick the abundant spermogones on account of the sweet juice that oozes from them."

The periods after which swelling of the stem and finally sporulation set in are variable. The time of the year at which the experiments were carried out had no influence on the incubation period, since all inoculations were made within two months of each other, the extreme dates being March 26 and May 23. The distance at which the plants were kept from the laboratory, on account of poor housing facilities, did not permit regular inspections. In one inoculation from *Pinus radiata* onto *P. radiata* the first swelling was observed after eleven months, while sporulation did not begin until thirty-five months after inoculation. In the experiment on the same pines reported in 1916 the first swellings were noted after seven months and sporulation began twenty-one months after inoculation. The corresponding figures for inoculation of *Pinus radiata* from *P. attenuata* are sixteen and twenty-nine months, of *Pinus muricata* from *P. radiata* eight and eleven and one-half months, of *Pinus radiata* from *P. radiata* (new series) eight and eleven months. The figures are given simply as general indications, since the plants have not been under constant observation and the periods elapsed between the different stages may be too long by a month or two. Differences in the growing conditions under which the plants were kept may account in a measure for the variations reported.

Gall formation was accompanied by typical witches'-brooms in eleven out of thirty-three cases. In some of the more recent inoculations witches'-brooms may still develop.

The galls produced are very typical of *Peridermium cerebrum* on *Pinus radiata*. They have the characteristic shape. In their youth they are either spherical or hemispherical, or they are more or less fusiform to pear-shaped, the gall being rather well set off against the sound part of the stem. Later the fusiform gall develops into the more characteristic spherical shape. In the younger galls the bark is smooth, showing plainly the scar of the inoculation wound. Later the bark becomes roughened, and after prolonged sporulation the dead bark scales give the gall surface a rugged appearance. The aecia appear as well defined, separate sori, which later may become partly confluent. The peridium is rather delicate and evanescent. The aecia break forth between the bark scales and continue to develop from year to year until the gall dies off. On older galls during the maximum of sporulation large parts may be covered with the orange colored spore masses, but the aecia are always easily traced.

[11] Grove, W. B. The British Rust Fungi. .... p. 24. Cambridge, 1913.

The spores produced are in all respects morphologically identical with those described for *Peridermium cerebrum*. Their measurements agree fully with those of the latter.

Galls were formed on parts of the stem from one to four years old. An inoculation of a five-year-old internode remained without result.

If there could exist a doubt as to the validity of the infections published in 1916, the results given here establish as a definite, incontrovertible fact that it is possible to infect young plants of *Pinus radiata* with aeciospores of *Peridermium cerebrum* from *Pinus radiata* and *P. attenuata*, and plants of *Pinus muricata* with spores from *Pinus radiata*, and that the resulting more or less spherical galls are in all details identical with the galls so common on various coast pines of California. In other words, the aeciospores of a heteroecious rust, capable of producing uredinia and telia on oaks, are also capable of producing aeciospores on pines by omitting the uredinial and telial stage altogether.

## FURTHER INOCULATION EXPERIMENTS

Aeciospores from the result of the direct aecial infection of *Pinus radiata* reported in 1916 were used repeatedly for inoculations on young plants of *Quercus agrifolia* and on *Q. engelmanni* (March 1, March 21, March 25, and April 2). More plants of *Quercus agrifolia*, *Q. chrysolepis*, *Q. wislizeni*, and *Q. engelmanni* were inoculated with aeciospores from *Pinus radiata* of various collections (dates of inoculation Feb. 13, April 2, April 15, May 10, and May 22). Inoculations cannot be made later than early spring because the oak leaves are in general fully matured in May. The experiments extended over several years. Without exception the inoculations failed to produce results.

The following inoculations were made with uredinial or telial material from oaks:

*March 9*. Urediniospores from *Quercus agrifolia* on *Quercus lobata*.

*March 29*. Urediniospores from *Quercus agrifolia* on *Q. lobata*.

*April 2*. Teliospores from *Quercus californica* on *Pinus radiata* (introduction of telial horns with well developed sporidia in wounds).

*April 18*. Teliospores from *Quercus agrifolia* on *Pinus radiata* (same method).

*August 26*. Teliospores from *Quercus californica* on *Pinus radiata* (same method).

All of these inoculations gave negative results. They were carried on through several years. The plants were kept under most favorable growing conditions.

Hedgcock[12] reports successful inoculations of leaves of *Quercus rubra*, *Q. emoryi*, *Q. marilandica*, *Q. gambelii*, and *Q. lobata* with urediniospores taken from the leaves of *Quercus gambelii*. *Quercus lobata* is an oak common in California, within the region in which *Peridermium cerebrum* is indigenous.

Besides these laboratory and greenhouse experiments, a considerable number of inoculations were made in the open, with due precautions, on leaves of sound *Quercus agrifolia* with aeciospores of *Peridermium cerebrum* on *Pinus radiata*. Not in a single case did they result in infection, although at the same time and shortly after, uredinial sori appeared on other oaks in quantity. It must be borne in mind that in nature many oaks seem to be perfectly immune, while others standing in the closest proximity to them are more or less heavily infected. The fact points to the existence of immune strains in *Quercus agrifolia*. If this is true, laboratory experiments will always be uncertain until it is possible to raise young oak plants from acorns of a tree known to be susceptible to infection. Unfortunately, the uredinial form is least frequently found on trees large enough to bear acorns.

While this difficulty may explain the failure to get positive results from inoculations on oaks, it does not do away with the corresponding failure to infect young pines with sporidia from oaks. Further inoculations of both types are on the way. It is not easy to secure good telial material. Telia are not very common. Their small size adds to the difficulties of collection. The period during which they mature appears to be rather short. It seems to vary from year to year and does not always coincide with the most favorable stage of development of the oak plants on hand.

### EXPERIMENTS WITH PERIDERMIUM HARKNESSII

*Peridermium cerebrum* is not the only rust fungus with facultative heteroecism. A series of inoculation experiments with *Peridermium harknessii* has shown that direct transfer of the fungus from pine to pine is equally possible.

The aeciospores of *P. harknessii* very readily produce uredinia and telia on *Castilleja miniata*. Inoculations on *Castilleja foliolosa* failed, perhaps due to the poor condition of the plants, which are difficult to raise in the laboratory.

In inoculating pines with aeciospores of *Peridermium harknessii* the same "slit" method was used as in the experiments with *Peridermium*

[12] Hedgcock, G. G. Notes on some diseases of trees in our national forests. I. 4 p. Washington, D. C., 1914. Paper read at the meeting of the American Phytopathological Society at Boston, Mass., December 30, 1909.

*cerebrum*. The galls are in full sporulation in July. The following is a synopsis of the results obtained.

| HOSTS | DATE OF INOCULATION | WOUNDS INOCULATED | POSITIVE INFECTION | PER CENT |
|---|---|---|---|---|
| P. pond.-P. rad. | July 21 | 3 | 1 | 33 |
| P. cont.-P. cont. | July 25 | 13 | 12 | 93 |
| P. cont.-P. jeffr. | July 25 | 21 | 12 | 57 |
| P. jeffr.-P. jeffr. | July 24 | 16 | 10 | 62 |
| P. jeffr.-P. cont. | July 24 | 13 | 10 | 77 |

Of a total of sixty-six inoculations forty-five, or 68 per cent were successful. In each case a gall was found exactly at the place of inoculation and at no other place. All control plants remained sound. The forty-five galls are accompanied by witches'-brooms in seventeen cases or 37 per cent.

In one inoculation, made in 1915, gall formation took place after eighteen months, while sporulation did not set in until forty-four months after inoculation. The remaining experiments are still too recent to show aecia. The galls appeared after eleven and twelve months. In no case could pycnia be observed. The transfer from *Pinus ponderosa* to *P. radiata*, the typical host of *Peridermium cerebrum* on the Coast, is of particular interest.

The results prove that the aeciospores of *Peridermium harknessii* are equally capable of producing uredinia and telia on certain Scrophulariaceae and aecia and aeciospores on pines.

### KLEBAHN'S EXPERIMENTS

Two years after the author's publication of the results of direct aecial transmittal from pine to pine, Klebahn[13] published similar results with *Peridermium pini* in support of Haack's[14] inconclusive experiments. The rigorous blockade before the entrance of the United States into the war evidently kept American scientific periodicals from reaching Germany, and Klebahn consequently was not aware that the problem of direct aecial infection had already been solved. The blister rust of *Pinus silvestris* in Europe consists, according to Klebahn, of two forms, one connected with *Cronartium asclepiadeum* (Willd.) Fries, which Klebahn calls *Peridermium cornui* Rostr. and Kleb., and another morphologically

[13] Klebahn, Heinrich. Peridermium pini (Willd.) Kleb. und seine Übertragung von Kiefer zu Kiefer. Flora, **111–112**: 194–207, ills., pl. 4–5. 1918.

[14] Meinecke, E. P. M., Op. cit., p. 237.

almost identical one, but not connecting with any Cronartium, called by him *Peridermium pini* (Willd.) Kleb. It is with the latter that Klebahn experimented. He operated with young trees raised from the seed of infected trees. The inoculations were made partly with wounds, partly without wounds. In both cases he obtained positive results, though more infections occurred through wounds. About 30 per cent of his inoculations were successful. The resulting aeciospores germinated readily on a film of water. The type of germination was invariably aecidioid, without a trace of promycelia and sporidia. It is particularly noteworthy that some of the infections resulted in the formation of pycnia. At the time of Klebahn's report these particular infections had not yet produced aecia. Klebahn is disinclined to believe that heteroecism exists in *Peridermium pini* side by side with the repetition of aecia. "Perhaps the acquisition of the faculty to produce aeciospores from aeciospores is accompanied in this case by the loss of heteroecism and the disappearance of teliospores." He proposes to solve this question indirectly through similar experiments with the undoubtedly heteroecious *Peridermium cornui*, and suggests experimentation with *Peridermium strobi*.

## GERMINATION STUDIES

Fromme[15] in a criticism of the author's first paper suggests that germination studies and perhaps cytological studies may be necessary in order to establish the true character of the spores, referring to the aeciospores used in the experiments. Since the publication of the first paper the author has made a great number of germination tests with the aeciospores resulting from infection with aeciospores of *Peridermium cerebrum* and *P. harknessii* as well as with spores from wild galls. The spores were dusted on a drop either of 5 per cent gelatine or, in by far the greater majority of cases, on a drop of tap water on slides which were placed on moistened filter paper in petri dishes. Germination under such conditions is always very abundant. In every case, without any exception, the single germ-tube produced was typically aecidioid. The tube growing into the air reaches great length, ten to fifteen times the length of the spore, is delicate and tapering towards the tip, occasionally branched, and often spirally curved, but it never shows the slightest tendency to produce sterigmata or sporidia, or any character which could possibly be interpreted as belonging to a promycelium. In order to leave no doubt on this point a very large number of spores (roughly about 800,000) were

[15] Fromme, F. D. Facultative heteroecism (?) of Peridermium harknessii and Cronartium quercus. Phytopathology, **6**: 411–412. 1916.

examined. No difference could be observed in the behavior of the spores used for inoculation and the spores resulting from the infection.

After two to three days the long germ-tubes are generally overgrown by moulds. In order to hold back the latter as well as to stunt the germ-tubes and induce them to develop typical promycelia on shorter tubes in case they were capable of doing so, a number of spore cultures were exposed to low temperatures. The result was a general elimination of the moulds and a very decided stunting of the germ-tubes, but no promycelia or anything resembling them were obtained.

It was thought possible that the actual contact with the tissues of the host plant might be necessary to stimulate the spores to produce promycelia and sporidia. A number of inoculations by the slit method were made and the spores examined after one to six days. In every case was the germ-tube typically aecidioid. Nothing even remotely resembling a promycelium or basidiospores could be detected.

## FACULTATIVE HETEROECISM

Fromme[16] has taken exception to the use of the term facultative heteroecism as applied to the faculty of omitting the alternate host, perhaps correctly so from his point of view, which considers *Peridermium harknessii* Moore in the older acceptance of the name and *Peridermium cerebrum* Peck as distinct. To anyone who believes that the California coast form connects with *Cronartium quercuum*, the term should appear logical. Hitherto heteroecism has been considered as obligate where it occurred in rust fungi, including *Peridermium cerebrum* Peck. Hedgcock's successful cross infection proves that the fungus can still exercise its faculty of heteroecism, while the direct infections from pine to pine show that it can omit the oak phase. Its heteroecism is no longer obligate, but facultative, optional. If a doubt can still exist concerning the California form of *Peridermium cerebrum*, none is possible with regard to the heteroecism of *Peridermium harknessii*. In other words, the results of our experiments show that heteroecism is not as fixed and rigid a phenomenon as has hitherto been believed.

The mere overwintering of the uredinial stage of *Cronartium cerebrum* does not constitute facultative heteroecism. It is the formation of teliospores and basidiospores which counts. In obligate heteroecism the organism should return to oak. To judge from the failure to infect California oaks the heteroecism of the fungus seems to have lost some of its obligate character.

[16] Op. cit., p. 411.

Why, according to Fromme, "a species must be capable of producing both generations on the host of one generation to be considered facultatively heteroecious" is not clear. The etymology of the Greek word heteroecism indicates plainly that it means the faculty of different generations of an organism to inhabit different hosts, just as autoecism indicates that an organism inhabits one host or host group only. An organism cannot be facultatively autoecious. By the mere fact that it produces different generations on different hosts it automatically becomes heteroecious by definition. Only heteroecism can be facultative or optional. In autoecism there can be no choice of hosts.

## INTERPRETATION

The outstanding features of our investigations may be summarized as follows:

In California a Peridermium, described by Moore as *P. harknessii* and now referred to *P. cerebrum*, abundantly produces galls on a number of pines, particularly *Pinus radiata*. The galls resemble very much, but not in all detail, the *Peridermium cerebrum* Peck of the East. Pycnia, common in typical *P. cerebrum*, have never been found. Witches'-brooms, rare in *P. cerebrum* of the East, are common on the California coast.

Side by side with *Peridermium cerebrum* there exists in California a sporophytic generation resembling in all respects *Cronartium cerebrum* (Peck) Hedgc. and Long. It occurs on a number of oaks commonly associated with the pines known to be hosts to *Peridermium cerebrum*. Both uredinial and telial stages are found. Infected oaks and pines may be located close together or may be so far distant from each other that inoculation through the air is excluded. Heavily infected individual oaks may stand in closest proximity to perfectly sound pines and vice versa. If both forms belong together, as is now accepted, they certainly show a remarkable independence of each other.

It is possible to infect pines directly with spores from the galls of the same species or certain other species. The percentage of successful inoculations is high. All inoculations of pines with sporidia from Californian oaks or of oaks with aeciospores from pines have failed.

The spores produced in the pine galls resulting from direct infection with spores from pine galls invariably show typical aecidioid germination, as do the spores from all wild pine galls.

The mycelium overwinters on the evergreen oaks and produces urediniospores and teliospores in spring.

On mountain pines a gall form, in gross appearance resembling that of the coast pines, is common, particularly on *Pinus contorta*. The aeciospores of this form, now called *Peridermium harknessii*, readily produce uredinia and telia on *Castilleia sp.* and typical galls with aecia and aeciospores on pines. Pycnia have never been found, with exception of abortive ones in a single case on *Pinus jeffreyi*, which may prove to refer to another Peridermium. Witches'-brooms are common. The resulting aeciospores show true aecidioid germination.

What is the interpretation of these facts?

Fromme[17] is of the opinion that the spores "although morphologically aecidiospores, (they) may be aeciospores, teliospores, or urediniospores in function, since all three may be borne catenulately in aecidioid fructifications. If the inoculated spores are aeciospores, the resultant spores must be urediniospores or teliospores (aeciospores do not reproduce aeciospores)." It is true that no definitely established case has been reported so far in which the aeciospores of a heteroecious rust reproduce aeciospores. Eriksson's results with *Puccinia arrhenateri* (Kleb.) Erikss. have never been confirmed. But what then is an aeciospore? A spore with all the morphological characters of an aeciospore, with aecidioid germination, failing to produce a promycelium, failing to produce sporidia, is difficult to classify as a teliospore. Cytological studies will show whether our spores are binucleate or uninucleate. If the former, they may be either aeciospores or urediniospores. If they are to be regarded as urediniospores we would have, in the same organism, two totally different kinds of urediniospores on two different hosts. Perhaps the spores are uninucleate. That would then be the only remaining character which they have in common with the teliospore, a teliospore in which the basidium itself, without formation of sporidia, directly infects the host. In that case the fungus would present the unique spectacle of forming no aeciospores but two distinct telial forms, also on two different hosts, one resembling in all detail except nuclear behavior true aeciospores, the other acting like normal teliospores. It is evidently too early to accept so extraordinary a possibility.

It seems far more probable that the accepted rule that aeciospores never produce aeciospores does not invariably hold true. Klebahn also considers the resulting spores as aeciospores. Perhaps the omission of the pycnia in the cycle has some significance in connection with the direct transmission of the rust from pine to pine by aeciospores. One might be inclined to assume that the disappearance of the pycnia adds to the sexual vigor of the aeciospore to such an extent as to make the latter

[17] Op. cit., p. 412.

sufficiently virulent to attack pines without having to pass through the sporophytic generation on oak or Castilleia respectively. This suggestion would be at variance with Olive's[18] views. He explains the jump from one host to hosts of very different systematic position on the ground of the profound and invigorating stimulus imparted by the sexual fusions. "The diploid aecidiospores, which are produced shortly following these fusions, are endowed with more vigor than any of the rest of the forms of rust spores; and are thus the most capable of infecting foreign protoplasm." Granted that the stimulus imparted by the sexual fusions may explain the jump from one host to another. But what is far more puzzling is that a spore form recently rendered sufficiently vigorous to effect that jump, should not be vigorous enough to re-infect the protoplasm it has so long been accustomed to. It may be, after all, that the omission of so fixed a character as the formation of telia in heteroecious rusts is far more momentous than the change from one host group to another. In *Cronartium harknessii* the percentage of successful inoculations of pines is decidedly lower than the percentage of infections of Castilleia.

In *Peridermium cerebrum* and *P. harknessii* the aeciospores possess both faculties, that of the jump to foreign protoplasm and that of re-infecting the old host. Perhaps such cases are more common than appears on the surface. Is what we observe in these forms an early stage in the development from autoecism to heteroecism, or are we watching the breaking down of heteroecism and an emancipation of generations?

### AECIAL INFECTION AND DISSEMINATION

It is evident that a heteroecious rust possessing, in addition to the usual mode of spreading through basidiospores, the faculty of directly infecting pines through aeciospores is particularly favored with regard to dissemination. This double faculty explains the extraordinary frequency of galls of *Peridermium harknessii* and *P. cerebrum*, both of which are capable of doing considerable damage. Seedlings are often killed. Older trees are stunted or deformed by the large galls on the stems. While certain hosts, such as *Pinus attenuata* and *P. sabiniana*, do not possess commercial value, the loss in *Pinus radiata*, one of the commonest garden and park trees of the coast, or in *P. ponderosa* and *P. jeffreyi*, both important timber trees, is not to be underestimated.

In the light of the experiments reported, it is far from impossible or even improbable that *Cronartium ribicola* may also be transmitted directly

[18] Olive, E. W. Origin of heteroecism in the rusts. Phytopathology, **1**: 139–140. 1911.

from pine to pine. Considering the very great importance of this disease it is highly desirable that similar experiments be carried out with aeciospores of the white pine blister rust.

## SUMMARY

To the host list of *Peridermium cerebrum* (the former *Peridermium harknessii* Moore) in California should be added *Pinus muricata* (and *P. halepensis*). The host list of *Cronartium cerebrum* Peck in California now also includes *Quercus californica*.

Previously reported direct infections of *Pinus radiata* with aeciospores from galls of *Peridermium cerebrum* on *Pinus radiata* are confirmed. Other direct infections with *Peridermium cerebrum* spores have been successful from *Pinus radiata* to *P. muricata*, and from *P. attenuata* to *Pinus radiata*.

*Peridermium harknessii* Moore, now confined to the gall form on mountain pines, though retaining its faculty easily to infect scrophulariaceous hosts and there to produce uredinia and telia, is also capable of reproducing galls, aecia, and aeciospores in direct inoculations from *Pinus contorta* to *P. contorta*, from *P. contorta* to *P. jeffreyi*, from *P. jeffreyi* to *P. jeffreyi*, from *P. jeffreyi* to *P. contorta*, and from *P. ponderosa* to *P. radiata*.

The germination of the resulting aeciospores in moist air is invariably truly aecidioid. No promycelium and no sporidia are formed. No pycnia are found. Witches'-brooms frequently accompany the galls.

The heteroecism of *Peridermium cerebrum* and *Peridermium harknessii* is facultative.

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# ON THE AMOUNT OF COPPER REQUIRED FOR THE CONTROL OF PHYTOPHTHORA INFESTANS ON POTATOES

O. Butler

With Three Figures in the Text

The year 1919 was a very favorable one for the development of late blight in New England, and therefore also a year eminently suited to a study of the relation between degree of control obtained and total quantity of copper applied per acre. It is of extreme importance that we know the minimum amount of copper required to give control and also the number of sprayings that must be applied with a Bordeaux mixture of any given strength, in order to secure the desired control; in other words, to determine whether frequency of application has any appreciable effect on the amount of copper that must be applied per acre. Upon these points an experiment carried out by the writer during the summer of 1919 supplies data that is not without interest.

In the experiment referred to, a potato field a trifle over 3 acres in extent was divided into twenty-three plots of four rows each, which were then sprayed, that is, all but no. 16, which was left as a witness, in the manner indicated, and with the fungicides named in table 1.

The spraying machine used in the experiments was an Iron Age equipped with triple action pump, and the pressure employed was 180 pounds. At the first spraying one nozzle was used per row, giving an application of 71.5 gallons per acre, while in the subsequent sprayings three nozzles were employed, giving an application of about 135 gallons per acre. When the three nozzles were first used a boom of the type illustrated in figure 1, *b*, was employed but was subsequently changed to the form illustrated in figure 1, *a*, which proved more satisfactory and covered the plants better.

The potatoes were sprayed on July 11 and subsequently thereafter as called for in the schedule (see table 1), the weather never once hindering the work. While the experimental field was located some seventeen odd miles from Durham, the nearest weather bureau station, the climatic data for the latter place will portray sufficiently accurately for our purpose the essential characteristics of the growing season as they pertain to the former. The graph (fig. 2) gives the daily maximum and minimum temperature and the rainfall for the period covered by the experiment.

TABLE 1

*Fungicides used and spraying schedule followed in experiments on control of light blight*

| FUNGICIDE USED | PLANTS SPRAYED WEEKLY | | PLANTS SPRAYED EVERY TWO WEEKS | | PLANTS SPRAYED EVERY THREE WEEKS | |
|---|---|---|---|---|---|---|
| | Plot number | Date sprayed | Plot number | Date sprayed | t m-ber | Date sprayed |
| 1 per cent Bordeaux mixture 1:1 | 1–17 | July 11, 18, 24<br>August 1, 8, 16, 22, 29<br>September 6, 12 | 6–20 | July 11, 24<br>August 8, 22<br>September 6 | 11 | July 11<br>August 1, 22<br>September 12 |
| 1 per cent Bordeaux mixture 1:05 | 2–18 | As above | 7–21 | As above | 12 | As above |
| 2 per cent Bordeaux mixture 1:05 | 3–19 | As above | 8–22 | As above | 13 | As above |
| Pyrox | 4 | As above† | 9 | As above | 14 | As above |
| Bordeaux mixture paste* | 5 | As above‡ | 10–23 | As above§ | 15 | As above |

* Manufactured by General Chemical Company, New York.

† On August 16, 2 per cent Bordeaux mixture was accidently used instead of Pyrox.

‡ Bordeaux mixture paste not used on August 29 and September 6, as our supply of material became exhausted.

§ Bordeaux mixture paste applied September 12 instead of September 6 (see note (‡) above).

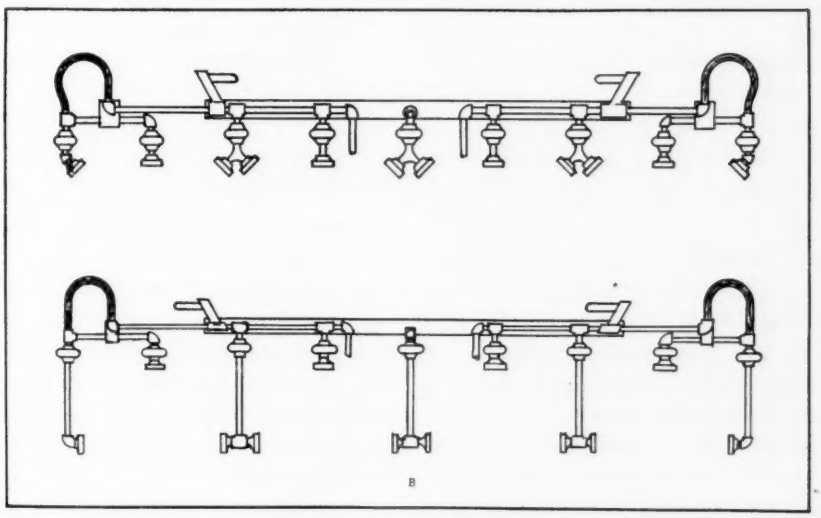

FIG. 1. TYPES OF BOOM USED IN SPRAYING EXPERIMENT

It will be noticed that, beginning September 9, we have cool wet weather eminently favorable for the development and spread of late blight, and, in effect, the malady proved extremely violent and destructive throughout the state of New Hampshire towards the close of the growing season. During the wet weather in September the late blight obtained a footing in the experimental field. On September 26 the foliage of the unsprayed plants was dead but the stalks were still green, while one week later the plants were entirely dead. The foliage of the plants sprayed once in three weeks with Pyrox was in bad condition on September 18, and on September 26

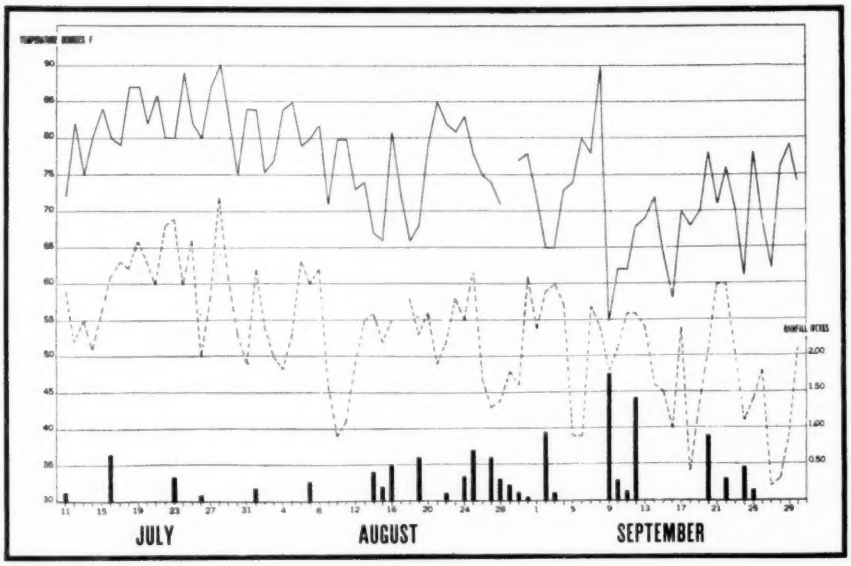


FIG. 2. DAILY MAXIMUM AND MINIMUM TEMPERATURES, AND RAINFALL AT DURHAM, N. H., FROM JULY 11 TO SEPTEMBER 31, 1919

———— = Maximum temperature
- - - - - - - = Minimum temperature
Vertical block column, = Rainfall

had almost completely withered. The foliage of the plants sprayed every three weeks with Bordeaux mixture paste was in poor condition on September 18, but the plants had not completely withered when a severe frost on October 9 completely killed the plants throughout the experimental field. The foliage of the plants in the plots other than those just considered remained green until the end, and showed no *inter se* differences worthy of comment. The foliage injury and premature death of the witness plants and those sprayed with Pyrox every three weeks, as well as the hardly less severe injury noted on the plants sprayed with

Bordeaux mixture paste every three weeks, was in large part due to early blight (*Macrosporium solani*) and not conspicuously to late blight. The late-blight fungus did not find as favorable a *nidus* for growth as would have obtained in the absence of early blight, though it was sufficiently virulent, as the data obtained at harvest will show, to make the experiment conclusive.

During the twelve days beginning October 18 the potatoes were harvested, the entire two central rows of each plot being taken for the data on tuber infection. The results obtained are indicated in table 2, in which is also given the amount of copper applied per acre during the season.

TABLE 2

*Effect on the control of late blight of strength of the fungicide used and of number of applications given*

| FUNGICIDE USED | PLANTS SPRAYED WEEKLY | | PLANTS SPRAYED EVERY TWO WEEKS | | PLANTS SPRAYED EVERY THREE WEEKS | |
|---|---|---|---|---|---|---|
| | Amount copper applied per acre | Per cent late-blight | Amount copper applied per acre | Per cent late-blight | Amount copper applied per acre | Per cent late-blight |
| | *pounds* | | *pounds* | | *pounds* | |
| 1 per cent Bordeaux mixture 1:1.... | 26.04 | 0.35 | 12.38 | 1.90 | 9.65 | 3.62 |
| 1 per cent Bordeaux mixture 1:05... | 26.04 | 0.13 | 12.38 | 0.60 | 9.65 | 3.07 |
| 2 per cent Bordeaux mxiture 1:05... | 52.09 | 0.00 | 24.77 | 0.00 | 19.30 | 0.76 |
| 2.5 per cent Pyrox..... | 8.91 | 0.64* | 1.83 | 4.65 | 1.43 | 14.28 |
| 2.75 per cent Bordeaux mixture paste. | 21.47 | 1.16† | 12.92 | 1.00† | 10.07 | 3.21 |

* Two per cent Bordeaux mixture 1:05 was applied once by mistake; the figure is therefore too low.

† Owing to lack of material, the spraying schedule was not fully carried out; the figure given is, therefore, too high.

A study of table 2 shows that absolute protection is afforded when between 24.7 pounds and 26 pounds of copper are applied per acre, and that whether this amount is applied in weekly or fortnightly sprayings the results obtained are substantially the same. To apply the necessary amount of copper is more important even than timeliness of application. It will be remembered that weather particularly favorable to the late-blight fungus supervened on September 9, and that conditions favorable to its spread and development continued until the plants were killed by frost. Now if we turn to the spraying schedule we will find that the last three-weekly spraying given before weather favorable to the late-blight fungus set in was on August 22, while the last weekly and fortnightly applications were given on September 6. In other words, in the case of the three-weekly sprayings, weather conducive to the development of

late blight supervened eighteen days after the last application had been made, whereas in the case of the weekly and fortnightly applications the interval was only three days. The plants sprayed every three weeks with 2 per cent Bordeaux mixture 1:05 yielded 0.76 per cent diseased tubers, substantially the same amount as 1 per cent Bordeaux mixture 1:05 applied fortnightly; 2 per cent Bordeaux mixture applied fortnightly

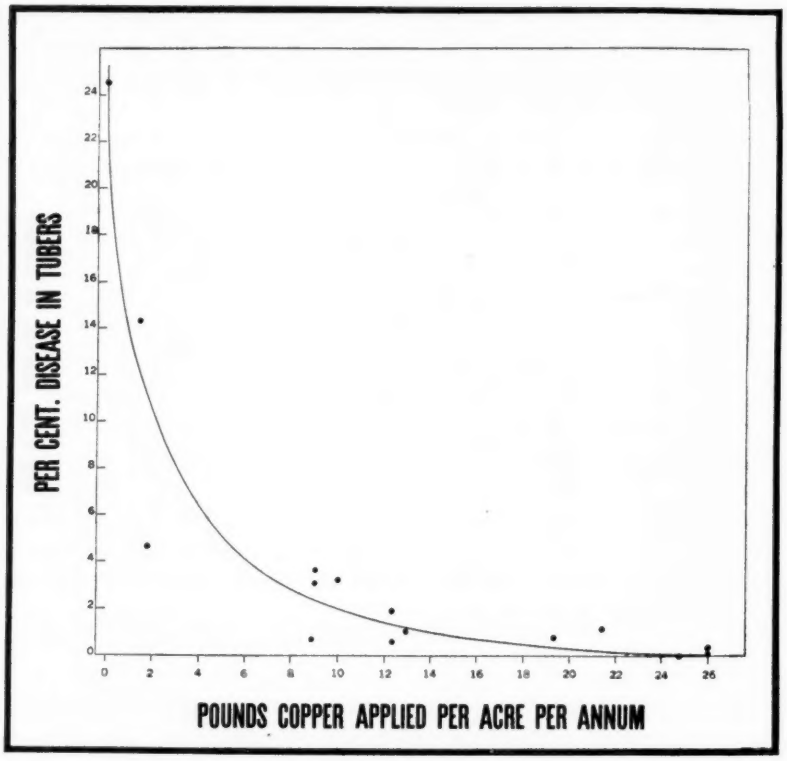


FIG. 3. CURVE SHOWING RELATION BETWEEN PER ACRE ANNUM APPLICATION OF COPPER AND LATE-BLIGHT INFECTION OF POTATO TUBERS

gave absolute protection, while 1 per cent Bordeaux mixture 1:05 sprayed weekly permitted very slight infection. Timeliness of application did not therefore determine the degree of freedom from late blight. If one plots the results secured in the experiment he will find the relation between protection obtained and the amount of copper applied per acre per annum to give the curve shown in the following graph (fig. 3). A study of this curve permits one to deduce that if a 0.5 per cent Bordeaux mixture

were used, then the potatoes would have to be sprayed twenty times in sixty-three days, *i.e.*, once every three days, in order to obtain the protection afforded by a 1 per cent Bordeaux mixture 1:05 applied weekly, or a 2 per cent Bordeaux mixture 1:05 used fortnightly. On the other hand, lengthening the interval between sprayings, which would be theoretically allowable, is subject to limitations, as is also the equally permissible increasing of the strength of the Bordeaux mixture employed. In the first place a Bordeaux mixture stronger than 2 per cent becomes difficult to handle; as a matter of fact, even a 2 per cent mixture does not handle satisfactorily, except when made directly in the spray tank, and an interval of more than three weeks between applications of a fungicide would leave new growth unduly long exposed to the dangers of infection. We are therefore obliged to adopt a middle ground. Just what this middle ground shall be must depend on the degree of protection sought and the economy of application desired. It is clear that one can spray with 2 per cent Bordeaux mixture 1:05 every three weeks with very satisfactory results and at a very considerable saving in cost of application; one can spray with 2 per cent Bordeaux mixture 1:05 every two weeks at less total expense and with results as regards protection identical with those obtained with 1 per cent Bordeaux mixture 1:05 applied weekly. But, and this is important, if we examine the data given in table 2 we will find that it is not only necessary to apply a certain amount of copper per acre per annum, but also that strictly equivalent protection is not obtained by simply making up any deficiency in strength of the Bordeaux mixture used by increasing the number of applications. The reader must not, however, infer from this that the unit copper in a strong Bordeaux mixture is more toxic than in a weak Bordeaux mixture; in other works, that there exists a relation between the strength at which the mixture is used and its toxicity to the late-blight fungus. There is no relation between concentration and toxicity, but there is a relation between composition and adhesiveness, and it is to this factor that the differences in protective power of the Bordeaux mixtures used are to be ascribed.

Now, if we turn to consideration of the proprietary fungicides employed, it will immediately be noticed that Bordeaux mixture paste, which contains when ready for use the copper equivalent of 1 per cent Bordeaux mixture, gives substantially the same protection; while Pyrox, which contains when ready for use only one-twenty-sixth of the copper present in a 1 per cent Bordeaux mixture, affords a protection that is far from satisfactory. Pyrox, it has been shown,[1] is not as adhesive as 1 per cent

[1] Butler, O., and Smith, T. O. Relative adhesiveness of the copper fungicides, Phytopathology **40**: 442, 1919.

Bordeaux mixture, so that its inability to give equivalent protection may be due both to a deficiency of copper and adhesive properties of a lower order. On the other hand, the behavior of Bordeaux mixture paste shows sufficiently that it is possible to manufacture a proprietary mixture possessing the properties of home-made Bordeaux mixture, but, in the present case at least, this was not accomplished by any economy in the use of copper. This fact should be especially borne in mind.

SUMMARY

1. The amount of copper that must be applied per acre per annum in order to prevent losses due to the attacks of *Phytophthora infestans* lies between 24 and 26 pounds.

2. One per cent Bordeaux mixture 1:05 is superior to 1 per cent Bordeaux mixture 1:1 for the control of late blight.

3. Two per cent Bordeaux mixture 1:05 applied fortnightly is superior to both 1 per cent Bordeaux mixture 1.05 and 1:1 applied every week.

4. Of the two proprietary copper fungicides experimented with, the one giving a mixture rich in copper was found very superior to the one giving a mixture weak in copper.

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## PHYTOPATHOLOGICAL NOTES

*Puccinia graminis on native Berberis canadensis.*[1]—*Berberis canadensis*, which is native in part of the Allegheny region of the eastern United States, has been known for some time to be susceptible to *Puccinia graminis*.[2] However, naturally infected bushes have not been reported heretofore, with one possible exception. An infected specimen of what was labeled *B. canadensis* was found by Dr. Arthur in the Schweinitz collection.[3] But, after carefully examining the collection, Dr. Arthur inclined to the opinion that the specimen was *B. vulgaris*.

During the summer of 1919 the Office of Cereal Investigations of the Bureau of Plant Industry, United States Department of Agriculture, coöperating with the states in which the work was done, made a barberry and rust survey of most of the states contiguous to the barberry eradication area. The object of the work was to ascertain the rôle of barberries in developing and spreading rust in those states in which the situation was little known. Particular attention was directed to a study of the possible relation of escaped and native barberries to rust development on cereals.

*Berberis canadensis* was found naturally infected in southern West Virginia and in Virginia. The junior writer found infected bushes in Monroe County, West Virginia, on May 7. The first infected bushes found in Virginia were observed by Professor Fromme and Professor Massey, May 18, near Blacksburg, Montgomery County. Later, infected bushes also were found in Pulaski, Wythe, and Smyth counties.

[1] The information contained in this note was accumulated by various people. The work was done coöperatively between the states involved and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture. The writers are under particular obligation to the following men for assistance and observational work: Dr. F. D. Fromme and Prof. A. B. Massey, Virginia Polytechnic Institute, Dr. N. J. Giddings, West Virginia Agricultural Experiment Station. W. N. Christopher, formerly field assistant, Office of Cereal Investigations, did much of the survey work in West Virginia, and Dr. C. A. Ludwig, formerly assistant pathologist, Office of Cereal Investigations, found one of the rust locations in Virginia.

[2] Levine, M. N. The epidemiology of cereal rusts in general and of the black stem rust in particular. Mimeographed paper, 1919.

[3] Arthur, J. C., and Bisby, G. R. An annotated translation of the part of Schweinitz's two papers giving the rusts of North America. Proc. Amer. Phil. Soc., **57**: 225–226, 1918.

It was quite evident that infection had occurred only a short time before May 7 in West Virginia, since most of the aecia were still immature. Nevertheless a few leaves were rusted in nearly every clump of bushes examined. Within a few weeks the infection became more general and more severe. During late May and early June thousands of heavily infected bushes were found in Monroe, Greenbrier, Summers, and Mercer counties, West Virginia. In fact, the bushes were so numerous that farmers were attempting to destroy them as weeds. An additional reason for the eradication of the bushes soon became clearly apparent. They were very numerous along fences, roadsides, and even along the edges of fields. It was evident, therefore, that the rust was likely to spread to the adjacent wheat fields.

By June 1 the rust had already spread from the bushes to grains and grasses in West Virginia. Many local rust epidemics began to develop by the middle of June, and, before harvest time, they reached considerable proportions. Very clearly many serious rust attacks were due to the proximity of rusted *B. canadensis* to wheat fields. In fact, there can be no question but that the presence of these bushes was detrimental to wheat growing in those regions in which observations were made in 1919. Several biologic forms of *P. graminis* undoubtedly were present, since, in addition to the common cereals, several wild grasses became infected. Apparently the rust spread only slightly from the barberries to wheat in Virginia, and no appreciable damage resulted. This may have been due partly to the early maturity of the wheat crop.

The association of the *B. canadensis* bushes with limestone formations was quite striking. Most of the bushes were small. This was very probably due to the fact that abundant seed apparently had been produced and the resulting seedlings were so badly crowded as to inhibit their normal development. The inaccessibility of the regions in which the observations were made probably accounts for the fact that the rust had not been reported on *B. canadensis* previously.

E. C. STAKMAN AND L. J. KRAKOVER.

*Sweet potato stem-rot and tomato wilt.*—The belief prevails in some sections of Maryland that tomatoes following sweet potatoes in the rotation become infected with wilt, the supposition being that the stem-rot of sweet potatoes and the wilt of tomatoes is caused by the same organism. That this is hardly likely would seem evident from the characteristic differences between the two organisms.

In view of the suspicions of the farmers, cross inoculations were made with *Fusarium hyperoxysporum* and *Fusarium lycopersici* on tomatoes and sweet potatoes respectively. *Fusarium hyperoxysporum* was isolated

from sweet potato plants collected in the part of Maryland where the two diseases occur and this organism was used in the inoculations. A culture of *F. lycopersici* was obtained from Mr. F. J. Pritchard who had previously proved its pathogenicity.

In 1918, cross inoculations were made with these two organisms by inserting spores and hyphae into the stems of the plants near the soil line. Check plants were made by inoculating sweet potatoes and tomatoes with *F. hyperoxysporum* and *F. lycopersici* respectively. These experiments were repeated in 1919. None of the sweet potatoes inoculated with *F. lycopersici* or tomatoes inoculated with *F. hyperoxysporum* became infected, while a considerable number of the check plants finally developed the disease. The results of these experiments show that the organisms were pathogenic to the host from which they were isolated but that the sweet potato fungus was not pathogenic to tomatoes, and vice versa. These experiments were carried out at the Arlington Experiment Farm near Washington, D. C.

L. L. HARTER AND J. L. WEIMER.

*Head smut in sorghum and maize.*—During the month of September, 1919, the writer observed in a volunteer crop of orange sorghum near Davis, California, an attack of head smut (*Sorosporium reilianum* (Kühn) McAlp.) averaging 15 per cent by plant count. The plants in all instances produced no seed in any head. The tillers were normal or almost normal in number but much reduced in diameter. Smutted plants matured earlier than smut-free plants, producing characteristically small, ravelled inflorescences. As the sorghum was cut for silage, the losses for infected plants included all the grain and fully one-half of the fodder.

The significant feature of the head-smut attack lay in the heavy infection in the volunteer field and the almost entire absence of attack in the adjacent planted field where barley had been the preceding crop. The explanation for this is given in the well known fact that this smut entirely or almost entirely makes its attack from the soil, where its spores lie viable from many months dispite seasonal disturbances. Soil infestation from bunt is common in the same region. Maize in adjacent fields was badly attacked by maize smut (*Ustilago zeae*) but no head smut was found. There is evidence that head smut has existed at Davis for a number of years.

In the peaty delta soils near Stockton the writer, at a later date, encountered head smut in a field of King Philips hybrid maize. The attack affected the maize plants, ears, and tassels much the same as in the attack in the heads of the saccharine sorghums. The grouping of the attacked plants, however, was quite distinct. The area observed in the maize

field was circular and most of the plants in the area were smutted In the volunteer sorghum field at Davis, on the contrary, the affected plants were scattered irregularly throughout the field. As maize production in the delta region is comparatively new, it may be that this fungus is of recent introduction and finds favorable conditions for propagation in these damp, peaty soils, which harbor so many fungous diseases. The infested area will be kept under observation.

W. W. MACKIE.

*Personals.* Dr. Luther P. Byars has resigned his position as pathologist in charge of nematode disease investigations in the Bureau of Plant Industry, to engage in business at Marion, South Carolina.

Mr. Wm. N. Ankeney, formerly scientific assistant in plant pathology in the Office of Cotton, Truck, and Forage Crop Investigations, Bureau of Plant Industry, has resigned this position to engage in farming at Xenia, Ohio.

Mr. Paul A. Murphy, Field Laboratory of Plant Pathology, Charlottetown, P. E. I., has resigned his position as officer in charge of potato disease investigation under the Dominion Department of Agriculture, and will take up work on April first as assistant with Dr. Pethybridge in the Division of Seeds and Plant Diseases in charge of plant pathological work in Ireland. His new address will be Royal College of Science, Dublin.

Mr. Julius Matz, who for the past year held the position of assistant pathologist at the Insular Experiment Station at Rio Piedras, Port Rico, has been appointed chief of the Division of Botany and Plant Pathology at the same station.

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[1] This list includes references, both American and foreign, to the literature of plant pathology and mycology of interest to pathologists. Foreign references published since January 1, 1917, have been included beginning with the list appearing in v. 7, no. 3, June, 1917.

All authors are urged to cooperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. Agric., Washington, D. C.

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## *ABSTRACTS OF PAPERS READ DURING THE FIRST ANNUAL MEETING OF THE CANADIAN BRANCH, AMERICAN PHYTOPATHOLOGICAL SOCIETY, ONTARIO AGRICULTURAL COLLEGE, GUELPH, ONTARIO, DECEMBER 11, 12, 1919. R. E. STONE, SECRETARY-TREASURER*

*Health and disease in plants.* F. L. DRAYTON

A plea for greater study of the host in plant pathological relationships. The importance of knowing the substances in the host most easily utilized by the parasite, and a better understanding of the relationship of host to parasite. A short description of the factors of environment and the important bearing on disease control of the relationship of a plant to its environment. Types of relative and complete immunity, the importance of knowing what constitutes disease resistance, and the necessity of having a method of recognizing it, other than by infection experiments. Coöperation and coördination essential factors in plant pathology.

*Decay in the timber of pulp and paper mill roofs.* (Illustrated by lantern slides.) R. J. BLAIR

The wood roofs of the Canadian pulp and paper mills are usually renewed every eight or ten years on account of decay. The roofs consist of a single layer of wood 1 to 6 inches in thickness or of two planks separated by an air space. The common fault is that moist air enters the spaces between the planks, reaches the upper part of the roof, cools off in cold weather, condensing the moisture, which maintains the wood in a moist condition so that it decays.

Control. Build the roof of red cedar, ventilate the mill to carry moisture away, heat the mill with dry air, and place a heat-insulating layer on the upper side of the roof-planks.

*Butt rots of the balsam fir in Quebec Province.* W. H. RANKIN

The so-called butt-rot disease of balsam fir is a complex of diseases caused by many different fungi. The most prevalent and destructive butt-rot is provisionally ascribed to *Fomes pinicola.* Butt-rot caused by *Polyporus schweinitzii* is also common. The *Fomes pinicola* (?) butt-rot occurs mixed with the butt-rot caused by *Polyporus schweinitzii,* and the earlier stages of these two decays have not been clearly separated so that they can be identified with certainty. Four or five other types of butt-rot of minor importance were studied but cannot be identified at present. In the case of the two common butt-rots, infection takes place largely through the tap root, although lateral roots are sometimes infected through wounds. There is a definite relation between the rate of growth of the balsam fir and the destructiveness of the two common butt-rots. Under conditions leading to fair or rapid growth, less than 10 per cent of the stands were found butt-rotted, and then only a negligible amount of damage was caused. Under conditions where growth is very slow, especially during the first thirty or forty years, the trees are uniformly found to be butt-rotted, irrespective of diameter. Butt-rot was found no more prevalent in regions where a heavy mortality has been experienced during the last ten years, following the bud-

worm, than it is in other regions. The same marked relation between rate of growth and prevalence of butt-rot held in both cases. Butt-rot was found to be in no way responsible for the heavy mortality following the bud-worm infestation. The heavy mortality following the bud-worm infestation seemed to be largely due to the physiological effects from which certain trees could not recover, although they were able to keep alive a few years. The abnormal mortality was found to have about ceased in regions where the bud-worm has been absent for four years or more.

*Needle blight of the white pine.* J. H. FAULL

Needle blight of the white pine was very prevalent on a large scale in some of the white pine forests of Ontario in 1917, 1918, and 1919. Experiments and observations show that the disease is physiological and not communicable, and that it is related to root injury. Young trees under favorable conditions recover; older trees may recover, though more slowly, and a variable percentage, up to 5 per cent, of old trees die.

*Witches broom of the Canada balsam and the alternate hosts of the causal organism.* R. E. STONE

Attention was called to the wide distribution of the witches broom of the Canada balsam and its close relation to a similar disease of European firs. An account of culture work was given, showing that the rust (*Peridermium elatinum*) had for its alternate hosts *Cerastium vulgatum* L. and *Stellaria media* (L.) Cyrill, producing *Melampsorella caryaphyllacearum* (D. C.) Schroeter.

Attention was also called to the witches broom of the spruces and the work that had been done in this genus, making it seem probable that the causal organism belonged to the same species.

An appeal was made for viable material from the spruces in order to test out more thoroughly the relation between the witches brooms on these plants related to the balsam.

The paper was illustrated with charts, photographs, and material.

*Some comparative observations upon the shape of the basidia and the mode of spore discharge in the Uredineae and the Hymenomycetes.* A. H. REGINALD BULLER

Throughout the Uredineae and Hymenomycetes the spores produced upon the basidia are violently discharged.

Dietel's observations (1912) on the violent discharge of the basidiospores of the Uredineae have been confirmed and extended to *Puccinia graminis*. Especial attention has also been paid to spore discharge in *Puccinia malvacearum* and *Endophyllum euphorbiae-sylvaticae*. The basidia of the grain rusts represented in Eriksson's Fungoid Diseases of Agricultural Plants (1912) were all abnormal in form.

In both Uredineae and Hymenomycetes, just before the discharge of a basidiospore, a drop of fluid is excreted where the spore is attached to the sterigma. The drop varies in size, according to the species, from one-third to one whole diameter of the spore. On discharge the drop is carred with the spore. Sometimes the drops may become abnormally large, and then discharge may not take place.

In many Uredineae the basidia are curved and the sterigmata are then placed on the convex outer side of the basidium. This causes the basidiospores to be directed toward an open space, with the result that, when discharge takes place, the spores are shot away so that they escape into free air. The curvature of the basidia of the Uredineae is therefore fraught with a beautiful physiological significance.

This communication was illustrated with models of straight and of curved basidia and with lantern slides.

*The pseudorhiza of certain saprophytic and parasitic Agaricineae.* A. H. REGINALD BULLER

The pseudorhiza is an organ which is developed from the base of the stipe in a number of saprophytic or parasitic Agaricineae, e.g., in *Collybia radicata* and *Coprinus macrorhizus*. It is known to field mycologists as a *rooting base*. It is developed on the fruit-bodies when these originate at the surface of buried roots, etc., and it is negatively geotropic. It serves to push up the rudiments of the pileus and the aerial stipe to the surface of the ground where they can expand without mechanical hindrance. Light entirely inhibits its development, so that the length of a pseudorhiza is always directly proportional to the thickness of the dark substratum which must be penetrated. Illustrated with lantern slides.

*A smut of western rye grass.* W. P. FRASER

This paper describes the morphology and life history of a smut of western rye grass (*Agropyron tenerum* Vasey) which was found to be widely distributed in the prairie provinces of Western Canada. The ordinary formalin treatment of the seed gave perfect control.

*Some observations made in inspecting for leaf roll and mosaic.* J. E. HOWITT

During the past two seasons (1918–1919) an effort has been made to improve the potato crop in southern Ontario. This involved disease surveys of the potato growing sections of southern and northern Ontario; a system of inspection and certification for disease in seed potatoes; and the testing for disease and yields of potato seed grown in northern Ontario, southern Ontario, and New Brunswick.

The seed from these sources was grown side by side on eighty different plots in forty counties of the Province during the past two years, and records kept of the percentage of serious disease and yield per acre. The results obtained and the observations made during the carrying on of this work may be summarized as follows:

Seed potatoes grown in northern Ontario are freer from leaf roll and mosaic and give larger yields per acre than those grown in southern Ontario and New Brunswick. Leaf roll is especially prevalent and severe in the southern and southwestern portions of southern Ontario. In most sections of southern Ontario, leaf roll appears to spread and cause more loss each year that the same seed is used. In northern Ontario, leaf roll does not seem to spread, nor to increase appreciably in amount from year to year in the same stock. Under climatic conditions such as we have in southern Ontario, mosaic appears to be suppressed some years; that is, when seed from mosaic stock is planted in some seasons, no mosaic is observed in the resulting crop. In northern Ontario there appears to be no such suppression of mosaic; it apparently appears in infected stock year after year. Mosaic evidently spreads in the one year from diseased to healthy plants and one of the chief agents in its transmission appears to be the leaf hopper (*Empoasca mali* Le Baron).

*New or little-known diseases of potatoes which cause "running-out" of seed.* (Illustrated.) PAUL A. MURPHY

Two diseases are described the effects of which are comparable to the worst types of leaf roll or curly dwarf.

Plants affected by the first disease, called provisionally "crinkle," are dwarfed, light green, bushy, or somewhat upright. The leaves are strongly corrugated (but not spotted), curve downwards at tips, and brittle. Affected plants are easily distinguishable from leaf roll, curly dwarf, and mosaic.

The second disease, called "leaf drop," causes extreme dwarfing, gradual death of the leaves from below upwards, and premature death. It may be identical with Appel's bacterial ring disease, and with a trouble described by F. C. Stewart. There are indications that both diseases are of European origin. Their distribution on this continent is unknown.

*Plant diseases and fungi comparatively new or rare in Ontario.* R. E. STONE AND J. E. HOWITT

New stem rot of tomatoes due to *Botrytis* sp. This disease was discovered in February, 1919. It differs from timber rot by the more extensive lesions and their wider distribution. It does not form sclerotia readily. Infection takes place only under excessively humid conditions and so far the disease has been discovered only in poorly ventilated greenhouses.

Blight of tomato seedlings due to *Phytophthora infestans* (Mont.) de Bary. This disease was present in poorly ventilated seed beds 1917–1918.

Wilt of egg plant due to *Nectria ipomoeae* Hals. was widespread this last summer and was observed from Sarnia to Ottawa. It was worst on land where egg plant had been previously grown.

Potato wilt due to *Verticillium alboatrum* McA. is quite common in southern central Ontario, and is easily mistaken for Fusarium wilt. In the field it may be distinguished from Fusarium wilt by the lesions which occur high up on the stem, and the tubers, although showing internal browning, seldom rot. The disease is common on Scotch varieties, especially Davies Warrior.

Bean mosaic was not seen until two years ago, but in 1918 was widespread in the province, occurring as scattered plants.

Cucumber mosaic is met with occasionally but has not yet become prominent. It should be watched for.

Leaf spot and shot hole of cherries and plums are very common, and last spring the ascogenous stages were collected at Guelph. *Coccomyces hiemalis* Higgins occurred on cherry and *Coccomyces prunophorae* Higgins on plums.

*Exoascus unilateralis* PK. was collected last year on *Prunus virginiana* L.

Strawberry leaf blotch or scorch, due to *Marssonia potentillae* (Desm.) Fisch, seems to be widespread but often confused with the leaf spot. *Marssonia potentillae* (Desm.) Fisch was followed by *Mollisia earliana* (Ell. and Ev.) Soci.

Snapdragon rust (*Puccinia anthirrini* Diet. & Holi.) continues to be troublesome. The disease was introduced on cuttings four years ago. It does not appear to be carried on the seed nor to winter over on old plants outdoors, but is carried over in the greenhouse.

Rust of statice (*Uromyces limonii* (D.C.) Lev.) was sent in the last year.

For the past two years barley has been badly attacked by leaf spot and streak (*Helminthosporium sativum* (P.) K. & B. (P. 111 & 13) and Hl. *teres*. Sacc.).

Barley has also been attacked by a stem disease, the fungus appearing like a Fusarium but the spores have not been seen. In some varieties the loss has been as high as 20 per cent.

Oats have also been attacked by *Helminthosporium avenae-sativae* (Briosi & Cav.) Lind.

Blue-grass in some counties presents a stunted and rusted appearance. A fungus *Leptosphaeria culmorum* Awd. is present.

Witches broom of black spruce due to the dwarf mistletoe (*Arceuthobium pusillum* Pk.) is present in our local swamps.

Killing of shade trees with kerosene at Hamilton in 1919. A number of shade trees were found to have been girdled by the placing of a band soaked in kerosene about the trees.

*Napicladium Tremulae. A new disease of the poplar.* A. W. MCCALLUM

This disease, which is well known in Europe, is recorded for the first time on this continent. It is characterized by the death of young shoots, which are bent double, become darkened in color and dried out, and the discoloration, drying out, and shrivelling of the leaves. The causal organism is one of the Pleosporaceae, *Didymosphaeria populina* Vuill. Only the conidial stage *Napicladium Tremulae* (Frank) Sacc. has been observed as yet. This disease is common in Ontario and Quebec and probable elsewhere throughout the range of the poplar. It has been collected on *Populus tremuloides* and *P. grandidentata.*

*Some data on peach yellows and little peach in Ontario.* L. CAESAR

The first appearance of yellows in Ontario was about the year 1874 and of little peach about 1895. Great outbreaks of yellows seem to have centered around the years 1881 and 1891. Another combined outbreak of yellows and little peach, but chiefly the latter, reached its height about 1911. In that year a new system of training inspectors was introduced, and as a result of the careful work done, the number of diseased trees was decreased from 60,000 in 1911 to fewer than 800 in 1918. The total loss from this outbreak was over $1,000,000. Experiments were conducted to determine possible methods of distribution of the diseases, and the following results were obtained:

1. The use of pits from diseased trees apparently is not a factor in distribution; for, though approximately 8 per cent of such pits will grow, if taken from trees still vigorous but clearly diseased, yet out of more than 100 seedlings thus obtained, none developed symptoms of disease. All these seedlings were kept for three years and 13 of them for six years.

2. Buds from affected trees inserted into healthy seedlings and trees produced disease in the majority of cases but not in all, the exceptions being possibly due to some of the buds being taken from very vigorous water-sprouts. Very few of the budded trees and seedlings—not over 1 per cent—showed symptoms of disease at the end of twelve months; most of them required from twenty-one to twenty-four months, and a few even thirty-four to thirty-six months.

3. Inoculating healthy trees with sap, filtered and non-filtered, from crushed diseased fruit, leaves, and twigs did not produce disease. (This experiment should be tried again by a different method.)

4. Rubbing the bark of diseased branches against the bark of healthy trees until both barks were badly ruptured did not produce the disease, even after four years' interval.

5. The presence for several years of diseased trees in an orchard does not, under some conditions at least, cause the neighboring trees to become diseased; for 5 trees, which, as the result of budding inoculation, showed disease clearly in 1914, were left in an orchard until they were dying; yet up to the present only one other tree in the orchard, and this one far removed from the affected trees, has become diseased. Orchard inspection however, and the experience of the past, tend to show that the presence of diseased trees is at times fraught with great danger and that their prompt removal is a safeguard against much loss when a general outbreak of either disease occurs.

*Inheritance of disease resistance in the common bean.* G. P. McROSTIE

The inheritance, as indicated by crosses between resistant and susceptible bean varieties, of resistance to three common bean diseases, anthracnose (*Colletotrichum lindemuthianum* (Sacc. and Magnus) Briosi and Cavara), dry root rot (*Fusarium phaseoli* (Martii) Burk), and mosaic, was reported on. Resistance to anthracnose was found to be dominant over susceptibility, while with the other two diseases, susceptibility was partially dominant over resistance. The segregation of resistant and susceptible plants in the second and subsequent generations followed definite Mendelian ratios. A number of desirable commercial types have been isolated which show resistance to the three diseases mentioned, and an attempt is being made to combine resistance to all three diseases in individual plants of various types.

*Abstract of talks given by* E. C. STAKMAN *at the meeting of the Canadian Phytopathological Society, at Guelph, Ontario, December 11 and 12, 1919*

The general subject of the discussion was "Recent Progress in the Investigation of Cereal Rusts."

The losses from cereal rusts have been enormous during the past several years. Quite evidently no adequate control measures were known. Extensive observations and investigations have been under way during the last four years in an attempt to ascertain more accurately the exact facts in the life history of the cereal rust fungi.

The results so far have shown rather clearly that cereal rusts overwinter in the uredinial stage in the southern part of the United States; but in the northern part of the country, while the leaf rusts overwinter readily in the uredinial stage, stem rust does so only rarely.

Extensive observations indicate plainly that a tremendous amount of stem rust infection in the spring comes from barberry rust. Control measures, therefore, have included an extensive barberry eradication campaign and careful cultural methods, including the destruction of weed grasses in so far as possible, careful fertilization, and the selection and development of rust-resistant varieties of grains. The task of developing resistant varieties is difficult. This is due to the fact that varieties resistant to one rust are not necessarily resistant to another. Furthermore there are so many biologic forms of stem rust on varieties of wheat that breeding becomes a regional problem.

Little progress has been made in the attempt to determine the real basis for resistance. Facts of such fundamental importance could best be obtained in a Phytopathological Institute such as the American Phytopathological Society is now attempting to establish.

[PHYTOPATHOLOGY for April (10: 185–271, Plate X) was issued May 10, 1920.]